Waves and Light Extra Study Questions

Short Answer

1. Determine the frequency for each of the following.
(a) A bouncing spring completes 10 vibrations in 7.6 s.
(b) An atom vibrates 2.5×10^{10} times in 5.0 s.
(c) A sound wave from a guitar string has a period of 3.3×10^{-3} s.

2. Find the period for each of the following:
(a) A pendulum swings back and forth 20 times in 15 s.
(b) A light wave has a frequency of 5.0×10^{14} Hz.
(c) The Moon travels around Earth six times in 163.8 d.

3. A 1.0 kg mass is hung from a spring whose constant, *k*, is 100 N/m. What is the period of oscillation of this mass when it is allowed to vibrate?

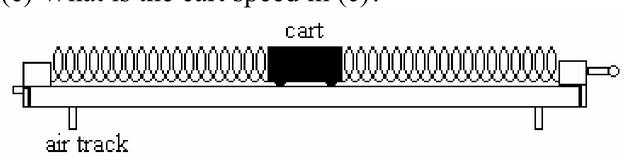
4. What is the period of a pendulum 0.40 m long?

5. Calculate the period for a spring whose force constant is 15 N/m, if the mass on the spring is 1.0 kg.

6. What is the period of a pendulum suspended from the CN Tower in Toronto by a light string 4.96×10^2 m long?

7. You are designing a pendulum clock. How far must the centre of mass of the simple pendulum be located from the pivot point of rotation to give the pendulum a period of 1.0 s?

8. A 0.020 kg cart is held between two identical, stretched springs on the air track illustrated. A force of 2.0 N is employed to hold the cart in a position 0.10 m from equilibrium. The cart is then released and allowed to vibrate from the 0.10 m position.
(a) What is the force constant for the springs/cart system?
(b) What is the frequency of vibration?
(c) What is the maximum kinetic energy of the cart?
(d) Where does (c) occur?
(e) What is the cart speed in (c)?



9. The wavelength of a water wave in a ripple tank is 0.080 m. If the frequency of the wave is 2.5 Hz, what is its speed?

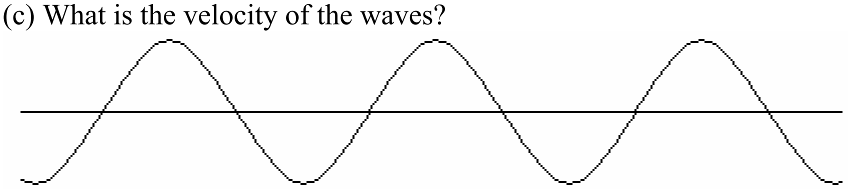
10. The period of a sound wave from a piano is 1.18×10^{-3} s. If the speed of the wave in air is 3.4×10^2 m/s, what is its wavelength?

11. A source with a frequency of 20 Hz produces water waves that have a wavelength of 3.0 cm. What is the speed of the waves?

12. A wave in a rope travels at a speed of 2.5 m/s. If the wavelength is 1.3 m, what is the period of the wave?

13. An FM station broadcasts radio signals with a frequency off 92.6 MHz. If these radio waves travel at a speed of 3.00×10^8 m/s, what is their wavelength?

14. A standing wave interference pattern is produced in a rope by a vibrator with a frequency of 28 Hz. If the wavelength of the waves is 20 cm, what is the distance between successive nodes?
15. The distance between the second and fifth nodes in a standing wave is 60 cm. What is the wavelength of the waves? What is the speed of the waves, if the source has a frequency of 25 Hz?
16. A tuning fork completes 2048 cycles in 8.0 s. What is its frequency?
17. The tine of a tuning fork vibrates with an amplitude of 0.13 cm. If the frequency of the fork is 200 Hz, what total distance will the tine travel in 1.00 min?
18. Thirty waves strike a concrete breakwater in 1.00 min. What is the period of the waves, in seconds?
19. Calculate the period when a spring, whose force constant is 20 N/m, is suspended vertically and loaded with a mass of 1.0 kg.
20. What is the period of an 80 cm pendulum on the Moon, where the acceleration due to gravity is 1.6 m/s^2?
21. On a particular planet, the period of a 0.50 m pendulum is 1.8 s. What is the acceleration due to gravity on this planet?
22. A pendulum completes 30 cycles in 15 s. Calculate its frequency and its period.
23. The distance between two successive nodes in a vibrating string is 10 cm. The frequency of the source is 30 Hz. What is the wavelength of the waves? What is their velocity?
24. This full-scale diagram shows a series of wave crests, all of which will pass a point in 0.50 s.
    (a) What is the wavelength in centimetres?
    (b) What is the frequency?
    (c) What is the velocity of the waves?



25. What are the wavelengths in air of the lowest and the highest audible frequencies if the range of human hearing is 20 Hz to 20 kHz and the speed of sound is 342 m/s?
26. Standing waves are set up in a string by a source vibrating at 100 Hz. Seven nodes are counted in a distance of 63 cm (including one node at each end).
    (a) What is the wavelength of the waves travelling in the string?
    (b) What is the speed of these waves?
27. If the fundamental frequency produced by a guitar string is 400 Hz, what are the frequencies of the second, third and fourth harmonics?
28. If two successive overtones of a vibrating string differ by 450 Hz, what is the frequency of the fundamental?
29. A water wave has a wavelength of 2.0 cm in the deep section of a tank and 1.5 cm in the shallow section. If the speed of the wave in the shallow water is 12 cm/s, what is its speed in the deep water?
30. The speed and the wavelength of a water wave in deep water are 18.0 cm/s and 2.0 cm, respectively. If the speed in shallow water is 10.0 cm/s, what is the corresponding wavelength?
31. A wave travels 0.75 times as fast in shallow water as it does in deep water. What will the wavelength of the wave in deep water be, if its wavelength is 2.7 cm in shallow water?

32. A 5.0 Hz water wave, travelling at 30 cm/s in deep water, enters shallow water so that the angle between the incident wave in the deep water and the boundary is 50°. If the speed of the wave in the shallow water is 27 cm/s, what is
(a) the angle of refraction in the shallow water
(b) the index of refraction for the media
(c) the wavelength of the wave in the shallow water

33. A 10 Hz water wave travels from deep water, where its speed is 40 cm/s, to shallow water where its speed is 30 cm/s. The angle of incidence is 30°. Find the following.
(a) the index of refraction
(b) the wavelengths in the two media
(c) the angle of refraction in the shallow water

34. Water waves travelling at a speed of 28 cm/s enter deeper water at an angle of incidence of 40°. What is the speed in the deeper water if the angle of refraction is 46°?

35. (a) The velocity of a sound wave in cold air is 320 m/s, and in warm air, 384 m/s. If the wavefront in cold air is nearly linear, what will be the angle of refraction in the warm air if the angle of incidence is 30°?
(b) What would be the angle of refraction if the angle of incidence were 60°? Explain your answer.

36. Two point sources generate identical waves that interfere in a ripple tank. The sources are located 5.0 cm apart, and the frequency of the waves is 8.0 Hz. A point on the first nodal line is located 10 cm from one source and 11 cm from the other.
(a) What is the wavelength of the waves?
(b) What is the speed of the waves?

37. A page in a student's notebook lists the following information, obtained from a ripple tank experiment with two point sources operating in phase: $n = 3$, $x_3 = 35$ cm, $L = 77$ cm, $d = 6.0$ cm, $\theta_3 = 25°$, and 5 crests = 4.2 cm. Determine the wavelength of the waves, using various methods.

38. In a ripple tank, a point on the third nodal line from the centre is 35 cm from one source and 42 cm from the other source. The sources are separated by 11.2 cm and vibrate in phase at 10.5 Hz. Calculate
(a) the wavelength of the waves
(b) the velocity of the waves

39. Two sources 6.0 cm apart, operating in phase, produce water waves. A student selects a point on the first nodal line and measures from it 30.0 cm to a point midway between the sources and 5.0 cm (on the perpendicular) to the right bisector.
(a) What is the wavelength of the waves?
(b) When the student selects a point on the second nodal line, he finds that it is 38.0 cm from the midpoint and 21.0 cm from the bisector. Determine the wavelength.
(c) What would be the value of the angle θ for distant points on the first and second nodal lines described above?

40. A straight wave is generated in a ripple tank, and the images on the screen below the ripple tank are "stopped" by using a six-slit stroboscope that turns 20 times in 25 s. The distance between the first and fifth bright lines is 12 cm.
(a) Assuming the strobe is at the highest "stopping" frequency, what is the frequency of the wave?
(b) What is the wavelength of the "shadow" wave?

41. In a ripple tank, one complete wave is sent out every $\frac{1}{10}$ s. The wave is stopped with a stroboscope, and it is found that the separation between the first and sixth crests is 12 cm.
(a) What is the wavelength?

(b) What is the speed of the wave?

42. The frequency of the vibrator in a ripple tank is 8.0 Hz.
(a) What would be the frequency of the resulting wave?
(b) If you were looking at the wave through a stroboscope with four slits open, what would you see if the rotational frequency of the strobe were (i) 1, (ii) 2, and (iii) 4 r/s?
(c) In order to measure the wavelength, you place an object of known length in the tank and find that the magnification factor is 2.5:1 for this screen. The distance on the screen between the first and sixth crests is 24 cm.
(i) What is the wavelength of the water wave?
(ii) What is the velocity of the wave in the ripple tank?

43. A circular wave having a speed of 30 cm/s is set up in a ripple tank. The radius of each wavefront differs from the preceding one by 3.0 cm. Calculate the frequency of the source.

44. A ripple tank wave passes from a deep to a shallow region with an angle of incidence of 60° and an angle of refraction of 45°. What are the ratios in the two media of the following?
(a) the wavelengths
(b) the velocities
(c) the frequencies

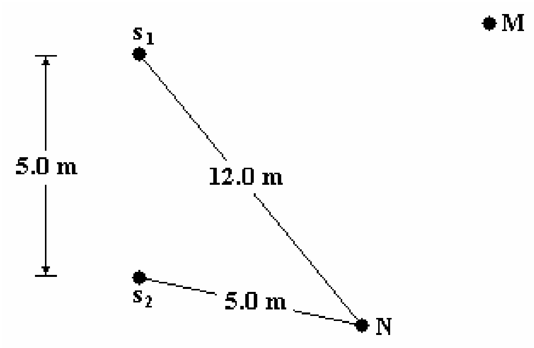
45. Longitudinal earthquake waves travelling through rock at 7.75 km/s enter a different body of rock at an angle of incidence of 20°. If the speed in the second body of rock is 7.72 km/s, what is the angle of refraction?

46. A student is carrying a small radio receiver that receives a signal from a transmitter located a few kilometres north of her position. It also receives from the same transmitter a signal reflected from the aluminum siding on a house a few hundred metres south of her position. As she carries the receiver 9.0 m north she notices that the sound level changes from a maximum to a minimum. Assuming that radio waves travel at the speed of light, what is the frequency of the radio transmitters?

47. An interference pattern is set up by two point sources of the same frequency, which are in phase. A point on the second nodal line is 25 cm from one source and 29.5 cm from the other source. The speed of the waves is 7.5 cm/s. Calculate the following.
(a) the wavelength
(b) the frequency of the sources

48. In a ripple tank experiment to demonstrate interference, two point sources having a common frequency of 6.0 Hz are used. The sources are 5.0 cm apart and are in phase. A metre stick is placed above the water, parallel to the line joining the two sources. The first nodal lines (one on each side of the central axis) cross the metre stick at the 35 cm and 55 cm marks. Each of the crossing points is 50 cm from the midpoint of the line joining the two sources. Calculate the wavelength and speed of the waves.

49. Two very small, identical loudspeakers, each of which is radiating sound uniformly in all directions, are placed at points S_1 and S_2 as shown in the diagram. They are connected to a source so that they radiate, in phase, a sound with a wavelength of 2.00 m. The speed of sound may be taken as 340 m/s.
(a) What is the frequency of the radiated sound?



(b) Point M, a nodal point, is 7.0 m from S_1 and more than 7.0 m from S_2. What are three possible distances M could be from S_2?
(c) Point N, also a nodal point, is located 12.0 m from S_1 and 5.0 m from S_2. On what nodal line is it located?

50. Red light with a wavelength of 650 nm travels from air into glass (n = 1.51).
(a) What will its velocity be in the glass?
(b) What will its wavelength be in the glass?

51. If the wavelength of orange light is 6.0×10^{-7} m in air, what is its frequency?

52. The frequency of a light is 3.80×10^{14} Hz. What is its wavelength in air, in nanometres?

53. A certain shade of violet light has a wavelength in air of 4.4×10^{-7} m. If the index of refraction of alcohol relative to air for violet light is 1.40, what is the wavelength of the violet light in alcohol?

54. The index of refraction of turpentine relative to air for red light is 1.47. A ray of red light ($\lambda = 6.5 \times 10^{-7}$ m) strikes an air-turpentine boundary with an angle of incidence of 40°.
(a) What is the wavelength of red light in turpentine?
(b) What is the angle of refraction in turpentine?

55. At what angle will 750 nm light produce a second minimum if the single-slit width is 2.0 μm?

56. If the first nodal line in a single-slit diffraction pattern occurs at an angle of 15° for light with a wavelength of 580 nm, what is the width of the slit?

57. Helium-neon laser light ($\lambda = 6.328 \times 10^{-7}$ m) passes through a single slit with a width of 43 μm onto a screen 3.0 m away. What is the separation of adjacent minima, other than the central maximum?

58. Light travels in water at three-quarters the speed it travels in air. If the angle of incidence in air is 30°, what would the angle of refraction be in water, according to a particle theorist? According to a wave theorist?

59. The wavelengths of the visible spectrum range from 400 nm to 750 nm. What is the range of the frequencies of visible light?

60. A radiation has a frequency of 3.75×10^{14} Hz. What is its wavelength? In what part of the spectrum is this radiation found? Assume that the radiation travels at the speed of light.

61. A certain shade of red light has a wavelength in air of 7.5×10^{-7} m. If the index of refraction of alcohol relative to air is 1.40, what is the wavelength of this red light in alcohol?

62. A student doing Young's experiment measures a distance of 6.0 cm between the first and seventh nodal points on a screen located 3.0 m from the slit plate.
(a) If the slit separation is 220 μm, what is the wavelength of the light being used?
(b) What is the colour of the light?

63. Red light, of wavelength 600 nm, passes through two parallel slits. Nodal lines are produced on a screen 3.0 m away. The distance between the 1st and the 10th nodal lines is 5.0 cm. What is the separation of the two slits?

64. A student measuring the wavelength of a narrow, monochromatic source uses a double slit with a separation of 0.15 mm. A second student places markers on a screen 2.0 m in front of the slits at the positions of successive dark bands in the pattern. She finds that the dark bands are 0.56 cm apart.
(a) Calculate the wavelength of the source in nanometres.
(b) Calculate what the spacing of the dark bands would be if a source of wavelength 600 nm were used.

65. In an interference experiment, red light with a wavelength of 6.0×10^{-7} m passes through a double slit. On a screen 1.5 m away, the distance between the 1st and 11th dark bands is 2.0 cm.
(a) What was the separation of the slits?
(b) What would the spacing be, between adjacent nodal lines, if blue light were used? ($\lambda_{blue} = 4.5 \times 10^{-7}$ m)

66. Monochromatic light from a point source illuminates two parallel, narrow slits. The centres of the slit openings are 0.80 mm apart. An interference pattern forms on a screen placed parallel to the plane of the slits and 50 cm away. The distance between two adjacent dark interference fringes is 0.30 mm.
(a) Determine the wavelength of the light.
(b) What would be the separation of the nodal lines if the slit centres were narrowed to 0.60 mm?

67. Monochromatic sodium light (589 nm) passes through a single slit 1.10×10^{-3} cm wide. If a screen is placed 2.00 m from the slit, calculate the positions of the first and second minimums, measured from the centre of the pattern.

68. If 600 nm light falls on a single slit 1.5×10^{-2} mm wide, what is the angular width of the central maximum?

69. Monochromatic light is directed through a slit 1.0×10^{-2} mm wide. If the angle contained between the first minimum on either side of the central maximum is 8°, what is the wavelength of the light?

70. An interference pattern is formed on a screen when helium-neon laser light ($\lambda = 6.328 \times 10^{7}$ m) is directed towards it through two slits. If the slits are 43 μm apart and the screen is 2.5 m away, what will be the separation of adjacent nodal lines?

71. (a) What is the spacing of the dark fringes in an interference pattern reflected from an air wedge between two microscope slides 10 cm long, separated at one end by a paper of thickness 0.10 mm, illuminated with red light of wavelength 660 nm?
(b) How would the spacing change if the wedge were filled with water (refractive index = 1.33)?

72. Light with a wavelength of 640 nm illuminates an air wedge 7.7 cm long. If the spacing between fringes is 0.19 cm, what is the thickness of the paper at the end of the air wedge?

73. A diffraction grating has 1000 slits/cm. When blue light (λ = 480 nm) is directed through the grating, what will be the separation of the bright points on a screen 4.00 m away?

74. Two plane glass surfaces are separated by an air film with a uniform thickness of 870 nm. If the film is illuminated perpendicularly by light having a wavelength of 580 nm, predict whether a bright or dark area will be seen by reflected light.

75. Light with a wavelength of 550 nm is used in a Michelson interferometer.
(a) If 100 fringes move by the reference point, how far has the movable mirror shifted?
(b) If the mirror moves 0.30 mm, how many fringes will move past the reference point?

Problem

76. A 2.5 kg object, vibrating with simple harmonic motion, has a frequency of 1.0 Hz and an amplitude of 0.50 m. What is the restoring force on the object at the ends of the swing?

77. The distance between successive crests in a series of water waves is 4.0 m, and the crests travel 9.0 m in 4.5 s. What is the frequency of the waves?

78. A grandfather clock had a pendulum exactly 1.00 m long and kept perfect time. A naughty grandson broke the pendulum. When repaired, it was exactly 2.0 cm shorter than before.
(a) Did the repaired clock lose or gain time?
(b) What would the accumulated error be after one day of operation?
(c) If the repaired clock were set correctly at midnight on New Year's Eve, when would it next indicate the correct time?

79. A spring vibrates with a frequency of 2.2 Hz when a mass of 0.50 kg is hung from it. What will its frequency be if a 1.00 kg mass is hung from it?

80. A series of strobe photos shows that a mass on a spring is located 10 cm from its equilibrium position 0.20 s after passing it, without having changed its direction of motion. What is the period of the vibrating mass if its amplitude is 20 cm?

81. What are the wavelengths in air of the lowest and the highest audible frequencies if the range of human hearing is 20 Hz to 20 kHz and the speed of sound is 342 m/s?

82. A 50 kg gymnast carefully steps onto a trampoline and finds that it is depressed vertically 30 cm when it supports her mass in equilibrium. Assuming the trampoline has negligible mass and that it vibrates with SHM, find the natural period of oscillation of the gymnast if her feet never leave the trampoline.

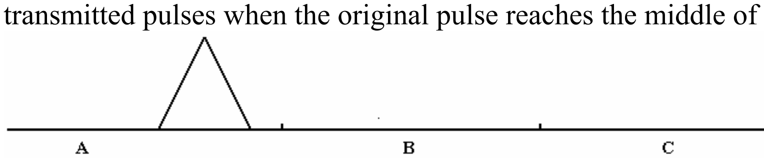
83. A pendulum vibrates with a period of 2.0 s and an amplitude of 50 cm. What will be its displacement from the equilibrium position 0.75 s after passing through it? 1.5 s after passing through it?

84. A given crest of a water wave requires 5.2 s to travel between two points on a fishing pier located 19 m apart. It is noted in a series of waves that 20 crests pass the first point in 17 s. What is the wavelength of the waves?

85. Two men are fishing from small boats located 30 m apart. Waves pass through the water, and each man's boat bobs up and down 15 times in 1.0 min. At a time when one boat is on a crest, the other one is in a trough, and there is one crest between the boats. What is the speed of the waves?

86. Two pulses move toward each other as illustrated. Sketch the resultant shape of the medium when the two pulses overlap.

87. A triangular pulse is created in medium A. The speeds of pulses in mediums A, B, and C are 1.0 cm/s, 2.0 cm/s, and 1.5 cm/s, respectively. Draw a diagram to show the nature and position of the reflected and transmitted pulses when the original pulse reaches the middle of medium C.



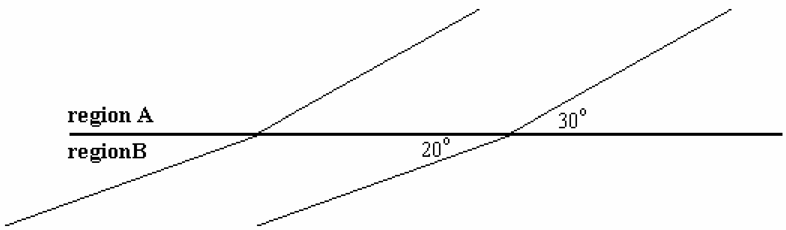
88. A straight wave in the deep region of water in a ripple tank has a speed of 24 cm/s and a frequency of 4.0 Hz. It strikes the boundary between deep and shallow water, the angle between the wavefront and the boundary being 40°. The speed in the shallow region is 15 cm/s.
(a) What angle does the refracted wavefront make with the boundary?

(b) What is the wavelength in shallow water?

89. The wavelength of a straight wave in the deep end of a ripple tank is 2.0 cm, and the frequency is 11 Hz. Wavefronts strike the boundary of the shallow section of the tank at an angle of 60° and are refracted at an angle of 30°. Calculate the speed of the wave in deep water and in shallow water.

90. When a straight periodic wave crosses a boundary between deep and shallow water, the following observations are made: ten wavefronts cross the boundary every 5.0 s, and the distance across three wavefronts is 24.0 cm in deep water and 18.0 cm in shallow water.
(a) Calculate the velocity of the wave in deep water and in shallow water.
(b) Calculate the relative refractive index.

91. A plane wave generator with a frequency of 6.0 Hz creates a water wave with a wavelength of 2.0 cm in region A of a ripple tank. The angle between the wave crests and the straight boundary between regions A and B of the tank is 30°. In region B the angle is 20°, as illustrated in the diagram.



(a) Use Snell's Law to determine the relative refractive index of the two regions.
(b) Find the velocity in each region.

92. An interference pattern is set up by two point sources of the same frequency, which are in phase. A point on the second nodal line is 25 cm from one source and 29.5 cm from the other source. The speed of the waves is 7.5 cm/s. Calculate the following.
(a) the wavelength
(b) the frequency of the sources

93. Two sources are vibrating in phase, and set up waves in a ripple tank. A point P on the second nodal line is 12.0 cm from source A and 20.0 cm from source B. When the sources are started, it takes 2.0 s for the first wave to reach the edge of the tank, 30 cm from the source. Find the velocity, wavelength, and frequency of the wave.

94. A police cruiser has an unusual radar speed trap set up. It has two transmitting antennae at the edge of a main road that runs north and south. One antenna is 2.0 m [west] of the other, and they are both fed from a common transmitter with a frequency of 3.0×10^9 Hz. These antennae can be considered as point sources of continuous radio waves. The trap is set for cars travelling south. A student drives his car along an east-west road that crosses the main road at a level intersection 100 m[north] of the radar trap. The student's car has a "radar detector", so he hears a series of beeps as he drives west through the intersection. If the time interval between successive quiet spots is $\frac{1}{5}$ s, as he crosses the main road, what is his speed?

95. The antenna of a radio station consists of two towers (to be considered as point sources) 400 m apart along an east-west line, broadcasting in phase. The broadcast frequency is 1.0×10^6 Hz. (Radio waves travel at 3.00×10^8 m/s.)
(a) In what directions is the intensity of the radio signal at a maximum for listeners 20 km north of the transmitter (but not necessarily directly north of it)?
(b) If the two towers were to transmit in opposite phase, state the directions in which the intensity would be at a minimum north of the transmitter.

96. A student doing Young's experiment finds that the distance between the first and the seventh nodal lines is 6.0 cm. If the screen is located 3.0 m from two slits, whose separation is 220 μm, what is the wavelength of the light?

97. Light with a wavelength of 670 nm passes through a slit with a width of 12 μm. Viewed on the screen, 30 cm away,
(a) How wide is the central maximum in (i) degrees and (ii) centimetres?
(b) What is the separation of adjacent minima (excluding the pair on either side of the central maximum)?

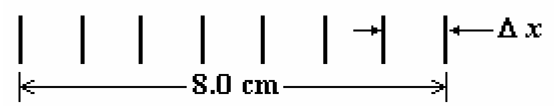
98. With two slits 0.12 mm apart, and a screen at a distance of 80 cm, the third bright line to one side of centre in an interference pattern is found to be displaced 9.0 mm from the central line. What was the wavelength of the light used? What colour was it?

99. When 640 nm light passes through a single slit, the central maximum produced on a screen 2.0 m away is 8.0 cm wide. What is the width of the slit?

100. A soap film with a thickness of 93 nm has a refractive index of 1.35. When viewed perpendicularly in white light, what colour is strongly reflected?

101. A camera lens (n = 1.52) is coated with a film of magnesium fluoride (n = 1.25). What should the least thickness of the film be to minimize reflected light with a wavelength of 550 nm?

102. A student measuring the wavelength produced by a sodium vapour lamp directed the sodium light through two slits with a separation of 0.15 mm. An interference pattern was created on the screen, 3.0 m away. The student found that the distance between the first and the eighth consecutive dark lines was 8.0 cm. What was the wavelength of the light emitted by the sodium vapour lamp?



103. In an interference experiment, red light (600 nm) passes through a double slit. On a screen 1.5 m away, the distance between the 1st and 11th dark bands is 13.2 cm. What is the separation of the slits? What would the spacing be, between adjacent nodal lines, if blue light (450 nm) were used?

104. The index of refraction of one type of glass is 1.50. According to the particle theory of light, what should be the speed of light in that glass?

105. An air wedge 9.8 cm long is separated at one end by a piece of paper 1.9×10^{-3} cm thick. The distance between centres of the first and eighth successive dark bands is 1.23 cm. What is the wavelength of the light being used?

Waves and Light Extra Study Questions
Answer Section

SHORT ANSWER

1. ANS:

   (a) $f = \dfrac{10}{7.6\ \text{s}}$

   $= 1.3\ \text{Hz}$

   (b) $f = \dfrac{2.5 \times 10^{10}}{5.0\ \text{s}}$

   $= 5.0 \times 10^{9}\ \text{Hz}$

   (c) $f = \dfrac{1}{T}$

   $= \dfrac{1}{3.3 \times 10^{-3}\ \text{s}}$

   $= 3.0 \times 10^{2}\ \text{Hz}$

   REF: K/U KEY: FOP 12.1, p.448 MSC: P

2. ANS:

   (a) $T = \dfrac{15\ \text{s}}{20}$

   $= 0.75\ \text{s}$

   (b) $T = \dfrac{1}{f}$

   $= \dfrac{1}{5.0 \times 10^{14}\ \text{Hz}}$

   $= 2.0 \times 10^{-15}\ \text{s}$

   (c) $T = \dfrac{163.8\ \text{d}}{6}$

   $= 27.3\ \text{d}$

   REF: K/U KEY: FOP 12.1, p.448 MSC: P

3. ANS:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$= 2\pi\sqrt{\frac{1.0\ \text{kg}}{100\ \text{N/m}}}$$

$$= 0.63\ \text{s}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.456
MSC: SP

4. ANS:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$= 2\pi\sqrt{\frac{0.40\ \text{m}}{9.8\ \text{m/s}^2}}$$

$$= 1.3\ \text{s}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.456
MSC: SP

5. ANS:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$= 2\pi\sqrt{\frac{1.0\ \text{kg}}{15\ \text{N/kg}}}$$

$$= 1.6\ \text{s}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.457
MSC: P

6. ANS:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$= 2\pi\sqrt{\frac{4.96 \times 10^2\ \text{m}}{9.8\ \text{m/s}^2}}$$

$$= 44.7\ \text{s} \quad \text{(assuming no wind)}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.457
MSC: P

7. ANS:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$l = g\left(\frac{T}{2\pi}\right)^2$$

$$= \left(9.8\ \text{m/s}^2\right)\left(\frac{1.0\ \text{s}}{2\pi}\right)^2$$

$$= 2.5 \times 10^{-1}\ \text{m, or } 25\ \text{cm}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.457
MSC: P

8. ANS:
(a) The two springs and the cart can be treated as a single spring and a cart.

$$k = \frac{F}{x}$$

$$= \frac{2.0\ \text{N}}{0.10\ \text{m}}$$

$$= 20\ \text{N/m}$$

(b) $T = 2\pi\sqrt{\frac{m}{k}}$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{20\ \text{N/m}}{0.020\ \text{kg}}}$$

$$= 5.0\ \text{Hz}$$

(c) $E_{k_{max}} = E_{p_{max}} = \frac{1}{2}kA^2$

$$= \frac{1}{2}(20\ \text{N/m})(0.10\ \text{m})^2$$

$$= 0.10\ \text{J}$$

(d) At the rest position.

(e) $E_k = \frac{1}{2}mv^2$

$$0.10\ \text{J} = \frac{1}{2}(0.020\ \text{kg})v^2$$

$$v = \pm\ 3.16\ \text{m/s}$$

$$= \pm\ 3.2\ \text{m/s}$$

Note the velocity of the cart is the same when it passes through the centre position going in either direction, as indicated by the + and – sign.

REF: K/U OBJ: 4.5 LOC: EM1.05 KEY: FOP 12.2, p.457
MSC: P

9. ANS:

$$v = f\lambda$$

$$= (2.5\ \text{Hz})(0.080\ \text{m})$$

$$= 0.20\ \text{m/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.4, p.463
MSC: SP

10. ANS:

$$v = f\lambda$$

$$\text{or}\quad v = \frac{\lambda}{T}$$

$$\lambda = vT$$

$$= \left(3.4 \times 10^2\ \text{m/s}\right)\left(1.18 \times 10^{-3}\ \text{s}\right)$$

$$= 0.40\ \text{m}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.4, p.464
MSC: SP

11. ANS:

$$v = f\lambda$$

$$= (20\ \text{Hz})\left(3.0 \times 10^{-2}\ \text{m}\right)$$

$$= 0.60\ \text{m/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.4, p.464
MSC: P

12. ANS:

$$T = \frac{\lambda}{v}$$
$$= \frac{1.3 \text{ m}}{2.5 \text{ m/s}}$$
$$= 0.52 \text{ s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.4, p.464
MSC: P

13. ANS:

$$\lambda = \frac{v}{f}$$
$$= \frac{3.00 \times 10^{8} \text{ m/s}}{92.6 \times 10^{6} \text{ Hz}}$$
$$= 3.2 \text{ m}$$

REF: K/U OBJ: 9.6 LOC: WA1.01 KEY: FOP 12.4, p.464
MSC: P

14. ANS:

$$\text{Distance between nodes} = \frac{1}{2}\lambda$$
$$= \frac{1}{2}(20 \text{ cm})$$
$$= 10 \text{ cm}$$

REF: K/U KEY: FOP 12.7, p.472 MSC: P

15. ANS:

$$\text{2nd to fifth nodes} = 1\frac{1}{2}\lambda$$
$$1\frac{1}{2}\lambda = 60 \text{ cm}$$
$$\lambda = 40 \text{ cm}$$

$$v = f\lambda$$
$$= (25 \text{ Hz})(40 \text{ cm})$$
$$= 10 \text{ m/s}$$

REF: K/U KEY: FOP 12.7, p.472 MSC: P

16. ANS:

$$f = \frac{2048 \text{ cycles}}{8.0 \text{ s}}$$

$$= 256 \text{ Hz}$$

$$= 2.6 \times 10^2 \text{ Hz}$$

REF: K/U KEY: FOP 12.10, p.478 MSC: P

17. ANS:

$$\text{One vibration} = 4(0.13 \text{ cm})$$

$$= 0.52 \text{ cm}$$

Distance travelled in one second is:

$$0.52 \times 200 \text{ Hz} \times 1.00 \text{ s} = 104 \text{ cm}$$

Distance travelled in one minute is:

$$(104 \text{ cm/s})(60 \text{ s/min}) = 6240 \text{ cm}$$

$$= 62 \text{ m}$$

REF: K/U KEY: FOP 12.10, p.478 MSC: P

18. ANS:

$$T = \frac{1.0 \text{ min}}{30 \text{ waves}}$$

$$= \frac{60 \text{ s}}{30 \text{ waves}}$$

$$= 2.0 \text{ s}$$

REF: K/U KEY: FOP 12.10, p.479 MSC: P

19. ANS:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$= 2\pi\sqrt{\frac{1.0 \text{ kg}}{20 \text{ N/m}}}$$

$$= 1.4 \text{ s}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.10, p.479
MSC: P

20. ANS:

$$T = 2\pi\sqrt{\frac{l}{g}}$$
$$= 2\pi\sqrt{\frac{0.80\ \text{m}}{1.6\ \text{m/s}^2}}$$
$$= 4.4\ \text{s}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.10, p.479
MSC: P

21. ANS:

$$g = \frac{4\pi^2 l}{T^2}$$
$$= \frac{4\pi^2(0.30\ \text{m})}{(1.8\ \text{s})^2}$$
$$= 6.1\ \text{m/s}^2$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.10, p.479
MSC: P

22. ANS:

$$f = \frac{\text{cycles}}{\text{time}}$$
$$= \frac{30\ \text{cycles}}{15\ \text{s}}$$
$$= 2.0\ \text{Hz}$$

$$T = \frac{1}{f}$$
$$= \frac{1}{2.0\ \text{Hz}}$$
$$= 0.50\ \text{s}$$

REF: K/U KEY: FOP 12.1, p.447 MSC: SP

23. ANS:

The distance between two successive nodes is $\frac{1}{2}\lambda$. Therefore, the wavelength is

2(10 cm) = 20 cm

$$v = f\lambda$$
$$= (30\ \text{Hz})(20\ \text{cm})$$
$$= 6.0 \times 10^{2}\ \text{cm/s}$$

REF: K/U KEY: FOP 12.7, p.472 MSC: P

24. ANS:

(a) $\lambda = 3.8$ cm by direct measurement

(b) $f = \dfrac{3\ \text{waves}}{0.50\ \text{s}}$

$= 6.0$ Hz

(c) $v = f\lambda$

$= (6.0\ \text{Hz})(3.8\ \text{cm})$

$= 22.8$ cm/s, or 23 cm/s

Alternate Solution:

$$v = \frac{d}{t}$$
$$= \frac{3\ \text{waves}(3.8\ \text{cm})}{0.50\ \text{s}}$$
$$= 23\ \text{cm/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.10, p.479
MSC: P

25. ANS:

$$\lambda = \frac{v}{f}$$

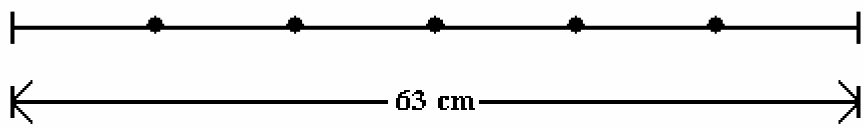
$$\lambda_1 = \frac{342\ \text{m/s}}{20\ \text{Hz}}$$
$$= 17.1\ \text{m, or } 17\ \text{m}$$

$$\lambda_2 = \frac{342\ \text{m/s}}{20 \times 10^{3}\ \text{Hz}}$$
$$= 17.1 \times 10^{-2}\ \text{m, or } 1.7 \times 10^{-2}\ \text{m}$$

REF: K/U, MC KEY: FOP 12.10, p.479 MSC: P

26. ANS:

(a)



$$6\left(\frac{1}{2}\lambda\right) = 63 \text{ cm}$$

$$\lambda = 21 \text{ cm}$$

(b) $v = f\lambda$

$$= (100 \text{ Hz})(0.21 \text{ m})$$

$$= 21 \text{ m/s}$$

REF: K/U KEY: FOP 12.10, p.480 MSC: P

27. ANS:
800 Hz, 1200 Hz, 1600 Hz

REF: K/U KEY: FOP 12.10, p.480 MSC: P

28. ANS:
Fundamental = difference between overtones

= 450 Hz

REF: K/U KEY: FOP 12.10, p.480 MSC: P

29. ANS:

$$\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

$$v_1 = \left(\frac{\lambda_1}{\lambda_2}\right)(v_2)$$

$$= \left(\frac{2.0 \text{ cm}}{1.5 \text{ cm}}\right)(12 \text{ cm/s})$$

$$= 16 \text{ cm/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.487
MSC: SP

30. ANS:

$$\frac{\lambda_s}{\lambda_d} = \frac{v_s}{v_d}$$

$$\lambda_s = \left(\frac{10 \text{ cm/s}}{18.0 \text{ cm/s}}\right)2.0 \text{ cm}$$

$$= 1.1 \text{ cm}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.487
MSC: P

31. ANS:

$$\lambda_d = \left|\frac{v_d}{v_s}\right|\lambda_s$$

$$= \frac{2.7\text{ cm}}{0.75}$$

$$= 3.6\text{ cm}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.487
MSC: P

32. ANS:

(a) $\dfrac{\sin i}{\sin R} = \dfrac{v_1}{v_2}$

$$\sin R = \left(\frac{v_2}{v_1}\right)\sin i$$

$$= \left(\frac{27\text{ cm/s}}{30\text{ cm/s}}\right)\sin 50°$$

$$= 0.689$$

$$R = 43.6°,\text{ or } 44°$$

(b) ${}_1n_2 = \dfrac{v_1}{v_2}$

$$= \frac{30\text{ cm/s}}{27\text{ cm/s}}$$

$$= 1.1$$

(c) The wavelength in the shallow water is

$$\lambda_2 = \frac{v_2}{f_2}$$

But $f_2 = f_1 = 5.0$ Hz

$$\lambda_2 = \frac{v_2}{f_2}$$

$$= \frac{27 \text{ cm/s}}{5.0 \text{ Hz}}$$

$$= 5.4 \text{ cm}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.489
MSC: SP

33. ANS:

(a) $n = \frac{v_d}{v_s}$

$$= \frac{40 \text{ cm/s}}{30 \text{ cm/s}}$$

$$= 1.33$$

(b) $v = f\lambda$

$$\lambda_d = \frac{v_d}{f}$$

$$= \frac{40 \text{ cm/s}}{10 \text{ Hz}}$$

$$= 4.0 \text{ cm}$$

$$\lambda_s = \left(\frac{v_s}{v_d}\right)\lambda_d$$

$$= \left(\frac{30 \text{ cm/s}}{20 \text{ cm/s}}\right)(4.0 \text{ cm})$$

$$= 3.0 \text{ cm}$$

(c) $\frac{\sin i}{\sin R} = n$

$$\sin R = \frac{\sin i}{n}$$

$$= \frac{\sin 30°}{1.33}$$

$$R = 22°$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.489

MSC: P

34. ANS:

$$\frac{\sin i}{\sin R} = \frac{v_s}{v_d}$$

$$v_d = v_s\left(\frac{\sin R}{\sin i}\right)$$

$$= 28 \text{ cm/s}\left(\frac{\sin 46°}{\sin 40°}\right)$$

$$= 31 \text{ cm/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.489
MSC: P

35. ANS:

(a) $\frac{\sin i}{\sin R} = \frac{v_1}{v_2}$

$$\sin R = \left(\frac{v_2}{v_1}\right)\sin i$$

$$= \left(\frac{384 \text{ m/s}}{320 \text{ m/s}}\right)\sin 30°$$

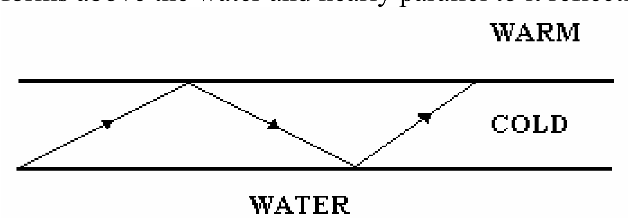
$$R = 36.9 \text{ or } 37°$$

(b) $\sin R = \left(\frac{384 \text{ m/s}}{320 \text{ m/s}}\right)(\sin 60°)$

$$= 1.04$$

R is undefined.

This occurs because the critical angle has been exceeded and all the sound waves are reflected. This occurs in the so-called "tunnel effect" where sound travels a long distance over water. A boundary of warm-cold air forms above the water and nearly parallel to it reflecting wave back to the water as illustrated.



REF: K/U, C OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.3, p.489
MSC: P

36. ANS:

(a) $\left|PS_1 - PS_2\right| = \left(n - \frac{1}{2}\right)\lambda$

$|11\text{ cm} - 10\text{ cm}| = \left(1 - \frac{1}{2}\right)\lambda$

$\lambda = 2.0\text{ cm}$

(b) $v = f\lambda$

$= (8.0\text{ Hz})(2.0\text{ cm})$

$= 16\text{ cm/s}$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.6, p.499
MSC: SP

37. ANS:

Method 1:

5 crests = $4\lambda = 4.2\text{ cm}$

$\lambda = \frac{4.2\text{ cm}}{4}$

$= 1.1\text{ cm}$

Method 2:

$\lambda = \frac{d\sin\theta}{\left(n - \frac{1}{2}\right)}$

$= \frac{(6.0\text{ cm})(\sin 25°)}{\left(3 - \frac{1}{2}\right)}$

$= 1.0\text{ cm}$

Method 3:

$\lambda = \left(\frac{x_n}{L}\right)\left(\frac{d}{n - \frac{1}{2}}\right)$

$= \left(\frac{35\text{ cm}}{77\text{ cm}}\right)\left(\frac{6.0\text{ cm}}{3 - \frac{1}{2}}\right)$

$= 1.1\text{ cm}$

Note that the three answers are slightly different because of experimental error and rounding off, which is to be expected.

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.6, p.500
MSC: SP

38. ANS:

(a) $\left|P_3S_1 - P_3S_2\right| = \left(n - \frac{1}{2}\right)\lambda$

$$\lambda = \frac{|35\text{ cm} - 42\text{ cm}|}{\left(3 - \frac{1}{2}\right)}$$

$$= 2.8\text{ cm}$$

(b) $v = f\lambda$

$$= (10.5\text{ Hz})(2.8\text{ cm})$$

$$= 29.4\text{ cm/s, or } 29\text{ cm/s}$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.6, p.500
MSC: P

39. ANS:

(a) $L = 30.0\text{ cm}$

$x = 5.0\text{ cm}$

$d = 6.0\text{ cm}$

$$\lambda = \left(\frac{x_n}{L}\right)\left(\frac{d}{1 - \frac{1}{2}}\right)$$

$$= \left(\frac{5.0\text{ cm}}{30.0\text{ cm}}\right)\left(\frac{6.0\text{ cm}}{1 - \frac{1}{2}}\right)$$

$$= 2.0\text{ cm}$$

(b) $\lambda = \left(\dfrac{x_n}{L}\right)\left(\dfrac{d}{1-\dfrac{1}{2}}\right)$

$$= \left(\frac{21.0\text{ cm}}{38.0\text{ cm}}\right)\left(\frac{6.0\text{ cm}}{2-\dfrac{1}{2}}\right)$$

$$= 2.2\text{ cm}$$

(c) $\sin\theta_n = \left(n - \dfrac{1}{2}\right)\dfrac{\lambda}{d}$

$$\sin\theta_1 = \frac{1}{2}\left(\frac{2.0\text{ cm}}{6.0\text{ cm}}\right)$$

$$\theta_1 = 9.6°$$

$$\sin\theta_2 = 1.5\left(\frac{2.2\text{ cm}}{6.0\text{ cm}}\right)$$

$$\theta_2 = 34°$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.6, p.500
MSC: P

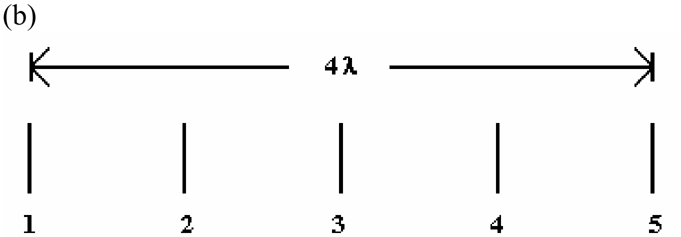
40. ANS:

(a) Frequency of strobe $= \dfrac{20}{25\text{ s}}(6)$

$$= 4.8\text{ Hz}$$

Thus the frequency of the wave is 4.8 Hz since it was “stopped” at the highest frequency.

(b)



The distance between the first and fifth wavelength is approximately 4λ.
Thus, $4\lambda = 12\text{ cm} = 3.0\text{ cm}$.

REF: K/U, I OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.510

MSC: P

41. ANS:

(a) $5\lambda = 12$ cm

$\lambda = 2.4$ cm

(b) Period of strobe $= \dfrac{1}{10}$ s

Thus the frequency of waves = 10 Hz

$$
\begin{aligned}
v &= f\lambda \\
&= (10\ \text{Hz})(2.4\ \text{cm}) \\
&= 24\ \text{cm/s}
\end{aligned}
$$

REF: K/U, I OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.510
MSC: P

42. ANS:

(a) 8.0 Hz

(b)

(i) Four slits, 1.0 Hz. This means the strobe frequency is one half the actual frequency. The wave would appear stationary, but would advance two wavelengths between successive looks.

(ii) Four slits, 2.0 Hz
Strobe frequency = frequency of waves
The wave would appear stationary.

(iii) Four slits, 4.0 Hz
Strobe frequency = 2 × wave frequency
There would be stationary "nodal points" half a wavelength apart. Between these, crests and troughs would alternate at each successive look. What would be seen is a series of "lines," alternating bright and dark, located one half wavelength apart!

(c)

(i) $5\lambda = 24$ cm

$\lambda = 4.8$ cm

Actual wavelength is:

$$4.8\ \text{cm}\left(\frac{1}{2.5}\right) = 1.92\ \text{cm, or } 1.9\ \text{cm}$$

(ii)
$$
\begin{aligned}
v &= f\lambda \\
&= (8.0\ \text{Hz})(1.92\ \text{cm}) \\
&= 15\ \text{cm/s}
\end{aligned}
$$

REF: K/U, C OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.510
MSC: P

43. ANS:

$$f = \frac{v}{\lambda}$$
$$= \frac{30\ \text{cm/s}}{3.0\ \text{cm}}$$
$$= 10\ \text{Hz}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.510
MSC: P

44. ANS:

$$\frac{\sin i}{\sin R} = n$$
$$n = \frac{\sin 60^\circ}{\sin 40^\circ}$$
$$= 1.225,\ \text{or } 1.2$$

(a) $n = \dfrac{\lambda_1}{\lambda_2}$

$= 1.2$

(b) $n = \dfrac{v_1}{v_2}$

$= 1.2$

(c) Frequency remains the same.
Thus, the ratio of the frequency is 1.0.

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.510
MSC: P

45. ANS:

$$\frac{\sin i}{\sin R} = \frac{v_1}{v_2}$$
$$\sin R = \left(\frac{7.72\ \text{km/s}}{7.75\ \text{km/s}}\right)\sin 20^\circ$$
$$R = 19.9^\circ$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

46. ANS:
The radio will respond to the direct signal and to the reflected signal. If they are in phase constructive interference will occur, and if out of phase destructive interference will occur. When the girl moves a distance of 9.0 m the intensity goes from a maximum to a minimum. Since the 9.0 m move produces a path difference of 18 m, $\frac{1}{2}\lambda = 18$ m and $\lambda = 36$ m.

$$f = \frac{v}{\lambda}$$
$$= \frac{3.00 \times 10^8 \text{ m/s}}{36 \text{ m}}$$
$$= 8.3 \times 10^6 \text{ Hz}$$
$$= 8.3 \text{ MHz}$$

REF: K/U, MC OBJ: 9.5 LOC: WA1.03 KEY: FOP 13.8, p.513
MSC: P

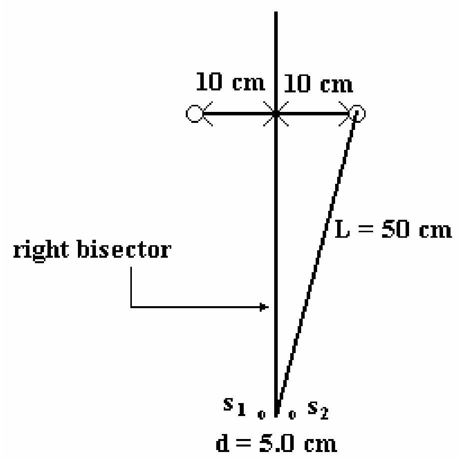
47. ANS:
(a) $\text{Path difference} = 25.9 \text{ cm} - 25 \text{ cm}$
$$= 4.5 \text{ cm}$$

$$\text{Path difference} = \left(n - \frac{1}{2}\right)\lambda$$
$$4.5 \text{ cm} = \left(2 - \frac{1}{2}\right)\lambda$$
$$\lambda = 3.0 \text{ cm}$$

(b) $f = \frac{v}{\lambda}$
$$= \frac{7.5 \text{ cm/s}}{3.0 \text{ cm}}$$
$$= 2.5 \text{ Hz}$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

48. ANS:



$$\lambda = \left(\frac{x}{L}\right)\left(\frac{d}{n - \frac{1}{2}}\right)$$

$$= \left(\frac{10\text{ cm}}{50\text{ cm}}\right)\left(\frac{5.0\text{ cm}}{1 - \frac{1}{2}}\right)$$

$$= 2.0\text{ cm}$$

$$v = f\lambda$$

$$= (6.0\text{ Hz})(2.0\text{ Hz})$$

$$= 12\text{ cm/s}$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.8, p.512
MSC: P

49. ANS:

(a) $f = \dfrac{v}{\lambda}$

$$= \frac{340\text{ m/s}}{2.00\text{ m}}$$

$$= 170\text{ Hz}$$

(b) Nodal lines occur when path difference is $\frac{1}{2}\lambda$, $1\frac{1}{2}\lambda$, $2\frac{1}{2}\lambda$, etc.

Since $\lambda = 2.00\text{ m}$, path difference could be 1.00 m, 3.00 m, and 5.00 m.

Three possible distance from S_2 are:
7.0 m + 1.0 = 8.0 m
7.0 m + 3.00 = 10.0 m

7.0 m + 5.00 = 12.0 m

(c) Path difference = $\left(n - \frac{1}{2}\right)\lambda$

$$7.0 \text{ m} = \left(n - \frac{1}{2}\right)(2.00 \text{ m})$$

$$n = 4$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.8, p.512
MSC: P

50. ANS:

(a) $n = \frac{v_a}{v_g}$

$$v_g = \frac{v_a}{n}$$

$$= \frac{300 \times 10^8 \text{ m/s}}{1.51}$$

$$= 1.99 \times 10^8 \text{ m/s}$$

(b) $\frac{v_a}{v_g} = \frac{\lambda_a}{\lambda_g}$

$$\lambda_g = \frac{v_g}{v_a}\lambda_a$$

$$= \left(\frac{1.99 \times 10^8 \text{ m/s}}{300 \times 10^8 \text{ m/s}}\right)650 \text{ nm}$$

$$= 430 \text{ nm}$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.5, p.533
MSC: SP

51. ANS:

$$f = \frac{c}{\lambda}$$

$$= \frac{3.00 \times 10^8 \text{ m/s}}{6.0 \times 10^{-7} \text{ m}}$$

$$= 5.0 \times 10^{14} \text{ Hz}$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.5, p.533
MSC: P

52. ANS:

$$\lambda = \frac{c}{f}$$

$$= \frac{3.00 \times 10^{8}\ \text{m/s}}{3.80 \times 10^{14}\ \text{Hz}}$$

$$= 789\ \text{nm}$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.5, p.533
MSC: P

53. ANS:

$$\frac{\lambda_{\text{air}}}{\lambda_{\text{Al}}} = n$$

$$\lambda_{\text{Al}} = \frac{\lambda_{\text{air}}}{n}$$

$$= \frac{4.4 \times 10^{-7}\ \text{m}}{1.40}$$

$$= 3.1 \times 10^{-7}\ \text{m}$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.5, p.533
MSC: P

54. ANS:

(a) $\frac{\lambda_{\text{A}}}{\lambda_{\text{T}}} = n$

$$\lambda_{\text{T}} = \frac{\lambda_{\text{A}}}{n}$$

$$= \frac{6.5 \times 10^{-7}\ \text{m}}{1.47}$$

$$= 4.4 \times 10^{-7}\ \text{m}$$

(b) $\dfrac{\sin i}{\sin R} = n$

$$\sin r = \frac{\sin i}{n}$$

$$= \frac{\sin 40^\circ}{1.47}$$

$$r = 26^\circ$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.5, p.533
MSC: P

55. ANS:

$$\sin \theta_2 = \frac{2\lambda}{w}$$

$$= \frac{(2)\left(750 \times 10^{-9}\ \mathrm{m}\right)}{\left(2.0 \times 10^{-6}\ \mathrm{m}\right)}$$

$$\theta_2 = 49^\circ$$

REF: K/U OBJ: 10.2 LOC: WAV.01 KEY: FOP 14.6, p.540
MSC: P

56. ANS:

$$\sin \theta_1 = \frac{\lambda}{w}$$

$$w = \frac{\lambda}{\sin \theta_1}$$

$$= \frac{580\ \mathrm{nm}}{\sin 15^\circ}$$

$$= 2.2 \times 10^{-6}\ \mathrm{m},\ \text{or}\ 2.2\ \mu\mathrm{m}$$

REF: K/U OBJ: 10.2 LOC: WAV.01 KEY: FOP 14.6, p.541
MSC: P

57. ANS:

$$\Delta y = \frac{L\lambda}{w}$$

$$= \frac{(3.0\text{ m})\left(6.328 \times 10^{-7}\text{ m}\right)}{43 \times 10^{-6}\text{ m}}$$

$$= 4.4 \times 10^{-2}\text{ m, or } 4.4\text{ cm}$$

REF: K/U OBJ: 10.2 LOC: WAV.01 KEY: FOP 14.6, p.541
MSC: P

58. ANS:
For particles:

$$\frac{\sin i}{\sin R} = \frac{3}{4}$$

$$\sin R = \frac{(4)(\sin 30°)}{3}$$

$$R = 42°$$

For waves:

$$\sin R = \frac{(3)(\sin 30°)}{4}$$

$$R = 22°$$

REF: K/U OBJ: 9.4 LOC: WAV.01 KEY: FOP 14.11, p.570
MSC: P

59. ANS:

$$f = \frac{c}{\lambda}$$

$$f_R = \frac{3.00 \times 10^{8}\text{ m/s}}{400 \times 10^{-9}\text{ m}}$$

$$= 7.50 \times 10^{14}\text{ Hz}$$

$$f_v = \frac{3.00 \times 10^{8}\text{ m/s}}{750 \times 10^{-9}\text{ m}}$$

$$= 4.00 \times 10^{14}\text{ Hz}$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.11, p.570
MSC: P

60. ANS:

$$\lambda = \frac{c}{f}$$

$$= \frac{3.00 \times 10^{8} \text{ m/s}}{3.75 \times 10^{14} \text{ Hz}}$$

$$= 8.00 \times 10^{-7} \text{ m, or } 800 \text{ nm}$$

This radiation is in the infrared region.

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.11, p.570
MSC: P

61. ANS:

$$\frac{\lambda_{\text{air}}}{\lambda_{\text{alcohol}}} = n$$

$$\lambda_{\text{alcohol}} = \frac{\lambda_{\text{air}}}{n}$$

$$= \frac{7.5 \times 10^{-7} \text{ m}}{1.40}$$

$$= 5.4 \times 10^{-7} \text{ m}$$

REF: K/U OBJ: 9.6 LOC: WA1.02 KEY: FOP 14.11, p.570
MSC: P

62. ANS:

(a) $6\Delta x = 6.0 \text{ cm}$

$$\Delta x = 1.0 \text{ cm}$$

$$\lambda = \Delta x \left(\frac{d}{L}\right)$$

$$= \left(1.0 \times 10^{-2} \text{ m}\right)\left(\frac{220 \times 10^{-6} \text{ m}}{3.0 \text{ m}}\right)$$

$$= 7.3 \times 10^{-7} \text{ m}$$

(b) red

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.11, p.570
MSC: P

63. ANS:

$$\Delta x = \frac{5.0 \text{ cm}}{9}$$
$$= 5.56 \times 10^{-3} \text{ m}$$

$$\lambda = \Delta x\left(\frac{d}{L}\right)$$
$$d = \frac{\lambda L}{\Delta x}$$
$$= \frac{\left(600 \times 10^{-9} \text{ m}\right)(3.0 \text{ m})}{5.56 \times 10^{-3} \text{ m}}$$
$$= 3.2 \times 10^{-4} \text{ m}$$

REF: K/U OBJ: 9.6 LOC: WA1.05 KEY: FOP 14.11, p.570
MSC: P

64. ANS:

(a) $\lambda = \Delta x\left(\dfrac{d}{L}\right)$

$$= (0.56 \text{ cm})\left(\frac{0.15 \text{ mm}}{2.0 \text{ m}}\right)$$
$$= \frac{\left(5.6 \times 10^{-3}\right)\left(1.5 \times 10^{-4} \text{ m}\right)}{2.0 \text{ m}}$$
$$= 4.2 \times 10^{-7} \text{ m}$$
$$= 4.2 \times 10^{2} \text{ nm}$$

(b) $\Delta x \propto \lambda$

$$\frac{\Delta x'}{\Delta x} = \frac{\lambda'}{\lambda}$$
$$\frac{\Delta x'}{0.56 \text{ cm}} = \frac{600 \text{ nm}}{420 \text{ nm}}$$
$$\Delta x' = 0.80 \text{ cm}$$
$$= 8.0 \times 10^{-3} \text{ m}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.11, p.570

MSC: P

65. ANS:

(a) $10\Delta x = 2.0\text{ cm}$

$\Delta x = 0.20\text{ cm}$

$$d = \frac{\lambda L}{\Delta x}$$

$$= \frac{\left(6.0 \times 10^{-7}\text{ m}\right)(1.5\text{ m})}{0.20 \times 10^{-2}\text{ m}}$$

$$= 4.5 \times 10^{-4}\text{ m}$$

(b) $\Delta x \propto \lambda$

$$\frac{\Delta x_b}{\Delta x_r} = \frac{\lambda_b}{\lambda_r}$$

$$\Delta x_b = \left(\frac{4.5 \times 10^{-7}\text{ m}}{6.0 \times 10^{-7}\text{ m}}\right)(0.20\text{ cm})$$

$$= 1.5 \times 10^{-1}\text{ cm}$$

$$= 1.5 \times 10^{-3}\text{ m}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.11, p.570

MSC: P

66. ANS:

(a) $\lambda = (\Delta x)\left(\frac{d}{L}\right)$

$$= \frac{(0.30\text{ mm})(0.80\text{ mm})}{500\text{ mm}}$$

$$= 4.8 \times 10^{-4}\text{ mm}$$

$$= 4.8 \times 10^{-7}\text{ m}$$

(b) $\Delta x \propto \frac{1}{d}$

$$\frac{\Delta x_2}{\Delta x_1} = \frac{d_1}{d_2}$$

$$\frac{\Delta x_2}{0.30 \text{ mm}} = \frac{0.80 \text{ mm}}{0.60 \text{ mm}}$$

$$\Delta x_2 = 0.40 \text{ mm}$$

$$= 4.0 \times 10^{-4} \text{ m}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.11, p.571
MSC: P

67. ANS:

$$y_1 = \frac{\lambda L}{w}$$

$$= \frac{(589 \text{ nm})(2.00 \text{ m})}{1.10 \times 10^{-5} \text{ m}}$$

$$= 1.07 \text{ m, or } 10.7 \text{ cm}$$

$$y_2 = 2\Delta y_1$$

$$= 2(10.7 \text{ cm})$$

$$= 21.4 \text{ cm}$$

REF: K/U OBJ: 10.2 LOC: WA1.05 KEY: FOP 14.11, p.571
MSC: P

68. ANS:

$$\sin \theta_1 = \frac{\lambda}{w}$$

$$= \frac{600 \text{ nm}}{1.5 \times 10^{-2} \text{ mm}}$$

$$= \frac{600 \times 10^{-9} \text{ m}}{1.5 \times 10^{-5} \text{ m}}$$

$$\theta_1 = 23°$$

Angular width is 2.3° × 2 = 4.6°.

REF: K/U OBJ: 10.2 LOC: WA1.05 KEY: FOP 14.11, p.571
MSC: P

69. ANS:

Angular width of central maximum is $2\theta_1$, thus $\theta_1 = 4°$

$$\sin\theta_1 = \frac{\lambda}{w}$$

$$\lambda = w\sin\theta_1$$

$$= \left(1.0 \times 10^{-5}\ \text{m}\right)(\sin 4^\circ)$$

$$= 6.98 \times 10^{-7}\ \text{m, or } 7.0 \times 10^{-7}\ \text{m}$$

REF: K/U OBJ: 10.2 LOC: WA1.05 KEY: FOP 14.11, p.571
MSC: P

70. ANS:

$$\Delta x = \frac{L\lambda}{d}$$

$$= \frac{(2.5\ \text{m})\left(6.328 \times 10^{-7}\ \text{m}\right)}{4.3 \times 10^{-6}\ \text{m}}$$

$$= 3.7 \times 10^{-2}\ \text{m, or } 3.7\ \text{cm}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.4, p.529
MSC: P

71. ANS:

(a) $\Delta x = L\left(\frac{\lambda}{2t}\right)$

$$= (10\ \text{cm})\left(\frac{6.60 \times 10^{-5}\ \text{cm}}{2\left(1.0 \times 10^{-2}\ \text{cm}\right)}\right)$$

$$= 3.3 \times 10^{-2}\ \text{cm, or } 0.33\ \text{mm}$$

(b) If air is replaced by water,

$$\lambda_{\text{water}} = \frac{\lambda_{\text{air}}}{n}$$

$$= \frac{6.60 \times 10^{-5}\ \text{cm}}{1.33}$$

$$= 4.96 \times 10^{-5}\ \text{cm}$$

$$\Delta x = \frac{(10\ \text{cm})\left(4.96 \times 10^{-5}\ \text{cm}\right)}{2\left(1.0 \times 10^{-2}\ \text{cm}\right)}$$

$$= 2.5 \times 10^{-2}\ \text{cm, or } 0.25\ \text{mm}$$

REF: K/U OBJ: 10.4 LOC: WA1.01 KEY: FOP 14.7, p.550
MSC: SP

72. ANS:

$$t = \frac{\lambda L}{2\Delta x}$$

$$= \frac{(640\ \text{nm})(7.7\ \text{cm})}{(2)(0.19\ \text{cm})}$$

$$= \frac{\left(640 \times 10^{-7}\ \text{cm}\right)(7.7\ \text{cm})}{(2)(0.19\ \text{cm})}$$

$$= 1.3 \times 10^{-3}\ \text{cm}$$

REF: K/U OBJ: 10.4 LOC: WA1.01 KEY: FOP 14.7, p.550
MSC: P

73. ANS:

$$d = \frac{1}{1000}\ \text{cm} = 1.00 \times 10^{-5}\ \text{m}$$

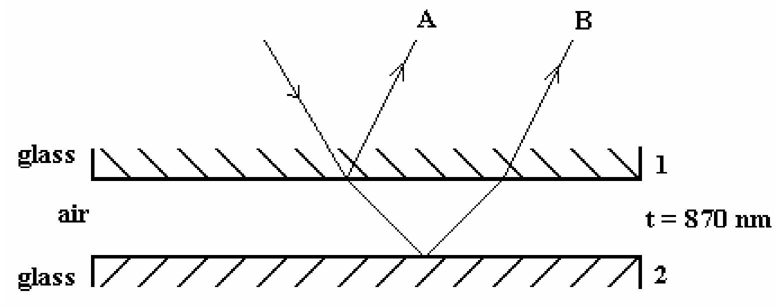
$$\Delta x = \frac{\lambda L}{d}$$

$$= \frac{(480\ \text{nm})(4.00\ \text{m})}{1.00 \times 10^{-5}\ \text{m}}$$

$$= 1.92 \times 10^{-1}\ \text{m, or } 19.2\ \text{cm}$$

REF: K/U OBJ: 10.3 LOC: WA1.01 KEY: FOP 14.11, p.571
MSC: P

74. ANS:



Ray A: No phase change at boundary 2
Ray B: 180° phase change at boundary 1

Extra distance travelled by ray B is
$2t = (2)(870\text{ nm}) = 1740\text{ nm}$

Since $\lambda = 580$ nm, the delay is

$$\frac{1740\text{ nm}}{580\text{ nm}} = 3\text{ complete cycles}$$

Because of phase change ray B is 180° out of phase with ray A producing destructive interference (dark).

REF: K/U, I OBJ: 10.4 LOC: WA1.01 KEY: FOP 14.11, p.571
MSC: P

75. ANS:
(a) Change in path length for 100 fingers is

$$100\lambda = (100)(500\text{ nm})$$
$$= 5.5 \times 10^{-5}\text{ m}$$

But, because of the reflection, the mirror only moves half as far,

$$\frac{1}{2}\left(5.5 \times 10^{-5}\text{ m}\right) = 2.8 \times 10^{-5}\text{ m}$$

(b) If mirror moves 0.30 mm, the distance the light travels increases is

$$2(0.30\text{ mm}) = 0.60\text{ mm, or } 6.0 \times 10^{-4}\text{ m}$$

$$N\lambda = 6.0 \times 10^{-4}\text{ m}$$

$$N = \frac{6.0 \times 10^{-4}\text{ m}}{5.5 \times 10^{-7}\text{ m}}$$
$$= 1090\text{ fringes}$$

REF: K/U OBJ: 10.7 LOC: WA3.03 KEY: FOP 14.11, p.571
MSC: P

PROBLEM

76. ANS:

$$T = 2\pi\sqrt{\frac{x}{a}}$$

But at maximum displacement $x = A$

$$T = 2\pi\sqrt{\frac{A}{a}}$$

$$a = A\left(\frac{2\pi}{T}\right)^2$$

$$= (0.50\text{ m})\left(\frac{2\pi}{1.0\text{ s}}\right)^2$$

$$= 19.7\text{ m/s}^2$$

$$F = ma$$

$$= (2.5\text{ kg})(19.7\text{ m/s}^2)$$

$$= 49.3\text{ N, or }49\text{ N}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.457
MSC: P

77. ANS:

$$v = \frac{\Delta d}{\Delta t}$$

$$= \frac{9.0\text{ m}}{4.5\text{ s}}$$

$$= 2.0\text{ m/s}$$

$$f = \frac{v}{\lambda}$$

$$= \frac{2.0\text{ m/s}}{4.0\text{ m}}$$

$$= 0.50\text{ Hz}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.4, p.463
MSC: SP

78. ANS:
(a) Gained, since length is shorter.

(b) $T_1 = 2\pi\sqrt{\dfrac{l_1}{g}}$

$$T_2 = 2\pi\sqrt{\dfrac{l_2}{g}}$$

$$T_2 - T_1 = \frac{2\pi}{\sqrt{g}}\left(1.00\text{ m} - \sqrt{0.98}\text{m}\right)$$
$$= 0.020\text{ s/swing}$$

$$T_2 = 2\pi\sqrt{\frac{1.00\text{ m}}{9.8\text{ m/s}^2}}$$
$$= 2.007\text{ s}$$

Thus, the clock runs about $\dfrac{0.020\text{ s}}{2.007\text{ s}} \times 100\% = 1.01\%$ faster.

The number of minutes in 24 h is 1440 min. Therefore the accumulated error in 24 h would be 1.01% or 14.5 min.

(c) The number of days required to gain 24 h would be
$$\frac{1440\text{ min/day}}{14.5\text{ min}} = 99.3\text{ days later}$$
or the morning of March 10 (assuming a leap year)

REF: K/U, MC OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.10, p.479
MSC: P

79. ANS:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Thus, $f \propto \dfrac{1}{\sqrt{m}}$

$$\frac{f_2}{f_1} = \sqrt{\frac{m_1}{m_2}}$$

$$f_2 = (2.2\text{ Hz})\sqrt{\frac{0.50\text{ kg}}{1.00\text{ kg}}}$$

$$= 1.56\text{ Hz, or }1.6\text{ Hz}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.10, p.479
MSC: P

80. ANS:

$$x = A\sin\frac{2\pi t}{T}$$

$$0.10\text{ m} = (0.20\text{ m})\sin\frac{2\pi(0.20\text{ s})}{T}$$

$$0.50 = \sin\frac{0.40\pi}{T}$$

Thus, $\frac{0.40\pi}{T} = 30°\left(\frac{2\pi}{360°}\right)$

$$\text{or } T = \frac{0.40\pi(360°)}{30°(2\pi)}$$

$$= 2.4\text{ s}$$

REF: K/U KEY: FOP 12.10, p.479 MSC: P

81. ANS:

$$\lambda = \frac{v}{f}$$

$$\lambda_1 = \frac{342\text{ m/s}}{20\text{ Hz}}$$

$$= 17.1\text{ m, or }17\text{ m}$$

$$\lambda_2 = \frac{342\text{ m/s}}{20\times10^3\text{ Hz}}$$

$$= 17.1\times10^{-2}\text{ m, or }1.7\times10^{-2}\text{ m}$$

REF: K/U, MC KEY: FOP 12.10, p.479 MSC: P

82. ANS:

$$F = mg$$
$$= (50\ \text{kg})(9.8\ \text{N/kg})$$
$$= 490\ \text{N}$$

This is the force exerted down upon the trampoline when she is standing on it.
The force constant for the trampoline is given by $F = kx$,

So, $k = \dfrac{F}{x}$
$$= \frac{490\ \text{N}}{0.30\ \text{m}}$$
$$= 1.6 \times 10^{3}\ \text{N/m}$$

For SHM:
$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$= 2\pi\sqrt{\frac{50\ \text{kg}}{1.6 \times 10^{3}\ \text{N/m}}}$$
$$= 1.1\ \text{s}$$

REF: K/U OBJ: 4.5 LOC: EM1.01 KEY: FOP 12.2, p.456
MSC: SP

83. ANS:
$$x_1 = A \sin \frac{2\pi t}{T}$$
$$= (0.50\ \text{m}) \sin \frac{360°(0.75\ \text{s})}{2.0\ \text{s}}$$
$$= (0.50\ \text{m}) \sin 135°$$
$$= 0.35\ \text{m}$$

Note: The positive value of x, indicates that the pendulum is on the same side of the equilibrium position that it entered as the problem began.
$$x_2 = (0.50\ \text{m}) \sin \frac{360°(1.5\ \text{s})}{2.0\ \text{s}}$$
$$= 0.50 \sin 270°$$
$$= -0.50\ \text{m}$$

The negative value of x_2 indicates that the pendulum has moved to the opposite side of the equilibrium position.

REF: K/U KEY: FOP 12.2, p.457 MSC: SP

84. ANS:

$$v = \frac{d}{t}$$
$$= \frac{19 \text{ m}}{5.2 \text{ s}}$$
$$= 3.65 \text{ m/s}$$

$$f = \frac{20}{17 s}$$
$$= 1.18 \text{ Hz}$$

$$\lambda = \frac{v}{f}$$
$$= \frac{3.65 \text{ m/s}}{1.18 \text{ Hz}}$$
$$= 3.1 \text{ m}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.4, p.464
MSC: P

85. ANS:

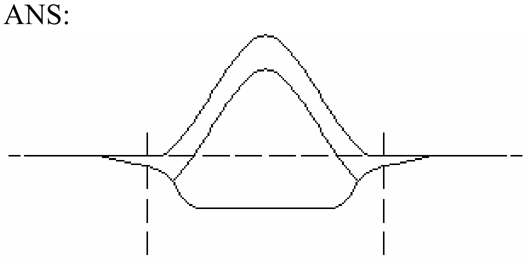
$$f = \frac{15}{60 \text{ s}}$$
$$= 0.25 \text{ Hz}$$

$$1.5\lambda = 30 \text{ m}$$
$$\lambda = 20 \text{ m}$$

$$v = f\lambda$$
$$= (0.25 \text{ Hz})(20 \text{ m})$$
$$= 5.0 \text{ m/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 12.10, p.479
MSC: P

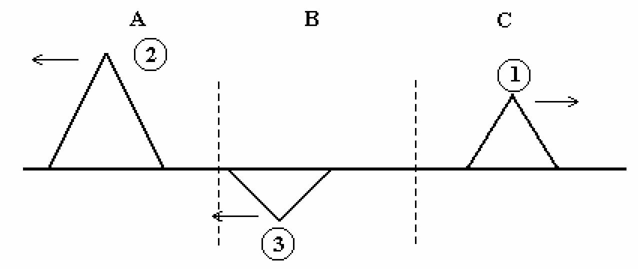
86. ANS:



REF: K/U KEY: FOP 12.10, p.480 MSC: P

87. ANS:

Although the pulse will double in length in medium B, it will drop back to 1.5 times as long in C. It will still be upright, but of smaller amplitude, shown as (1). An upright reflection from face AB will be moving left in A with the original length and smaller amplitude, shown as (2). An inverted reflection from face BC will be moving left in B, with twice the original length and smaller amplitude, shown as (3). Think of the fun when (3) transmits into A and also reflects with inversion back to being upright in B!



REF: K/U KEY: FOP 12.10, p.480 MSC: P

88. ANS:

(a) $v_d = 24$ cm/s

$f = 4.0$ Hz

$i = 40°$

$v_s = 15$ cm/s

$$\frac{\sin i}{\sin R} = \frac{v_d}{v_s}$$

$$\sin R = \sin i\left(\frac{v_s}{v_d}\right)$$

$$= \sin 40°\left(\frac{15\text{ cm/s}}{24\text{ cm/s}}\right)$$

$$R = 24°$$

(b) $\lambda_1 = \dfrac{v_1}{f}$

$$= \frac{24\text{ cm/s}}{4.0\text{ Hz}}$$

$$= 6.0\text{ cm}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$\lambda_2 = \left(\frac{v_2}{v_1}\right)\lambda_1$$

$$= \left(\frac{15\ \text{cm/s}}{24\ \text{cm/s}}\right)(6.0\ \text{cm})$$

$$= 3.7 \text{ or } 3.8\ \text{cm}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

89. ANS:

$$v_1 = f\lambda_1$$

$$= (11\ \text{Hz})(2.0\ \text{cm})$$

$$= 22\text{cm/s}$$

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin R}$$

$$v_2 = \left(\frac{\sin R}{\sin i}\right)v_1$$

$$= \left(\frac{\sin 30^\circ}{\sin 60^\circ}\right)(22\ \text{cm/s})$$

$$= 12.7\ \text{cm/s or } 13\ \text{cm/s}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

90. ANS:

(a) $f = \dfrac{10}{5.0\ \text{s}}$

$$= 2.0\ \text{Hz}$$

$$2\lambda_d = 24.0\ \text{cm}$$

$$\lambda_d = 12.0\ \text{cm}$$

$$v_d = f\lambda_d$$

$$= (2.0\ \text{Hz})(12.0\ \text{cm})$$

$$= 24\ \text{cm/s}$$

$$2\lambda_s = 18.0 \text{ cm}$$
$$\lambda_s = 9.0 \text{ cm}$$

$$\begin{aligned} v &= f\lambda \\ &= (2.0 \text{ Hz})(9.0 \text{ cm}) \\ &= 18 \text{ cm/s} \end{aligned}$$

(b) $$\begin{aligned} n &= \frac{v_d}{v_s} \\ &= \frac{24 \text{ cm/s}}{18 \text{ cm/s}} \\ &= 1.33, \text{ or } 1.3 \end{aligned}$$

Note: the phrase "across three wavefronts" was a bit ambiguous!

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

91. ANS:

(a) $$\frac{\sin i}{\sin R} = n$$
$$\begin{aligned} n &= \frac{\sin 30^\circ}{\sin 20^\circ} \\ &= 1.46 \end{aligned}$$

(b) $\lambda_A = 2.0$ cm by measurement

$\lambda_B = 1.35$ cm by measurement (1.36 cm by calculation)

$$\begin{aligned} v_A &= f\lambda_A \\ &= (6.0 \text{ Hz})(2.0 \text{ cm}) \\ &= 12 \text{ cm/s} \end{aligned}$$

$$\begin{aligned} v_B &= f\lambda_B \\ &= (6.0 \text{ Hz})(1.36 \text{ cm}) \\ &= 8.2 \text{ cm/s} \end{aligned}$$

REF: K/U OBJ: 9.1 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

92. ANS:

(a) Path difference = 25.9 cm − 25 cm

$$= 4.5\text{ cm}$$

$$\text{Path difference} = \left(n - \frac{1}{2}\right)\lambda$$

$$4.5\text{ cm} = \left(2 - \frac{1}{2}\right)\lambda$$

$$\lambda = 3.0\text{ cm}$$

(b) $f = \dfrac{v}{\lambda}$

$$= \frac{7.5\text{ cm/s}}{3.0\text{ cm}}$$

$$= 2.5\text{ Hz}$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.8, p.511
MSC: P

93. ANS:

Path difference = 20.0 cm − 12.0 cm

$$= 8.0\text{ cm}$$

$$\text{Path difference} = \left(n - \frac{1}{2}\right)\lambda$$

$$8.0\text{ cm} = \left(2 - \frac{1}{2}\right)\lambda$$

$$\lambda = \frac{8.0\text{ cm}}{1.5}$$

$$= 5.3\text{ cm}$$

$$v = \frac{d}{t}$$

$$= \frac{30\text{ cm}}{2.0\text{ s}}$$

$$= 15\text{ cm/s}$$

$$f = \frac{v}{\lambda}$$

$$= \frac{15 \text{ cm/s}}{5.3 \text{ cm}}$$

$$= 2.8 \text{ Hz}$$

REF: K/U OBJ: 9.3 LOC: WA1.01 KEY: FOP 13.8, p.512
MSC: P

94. ANS:

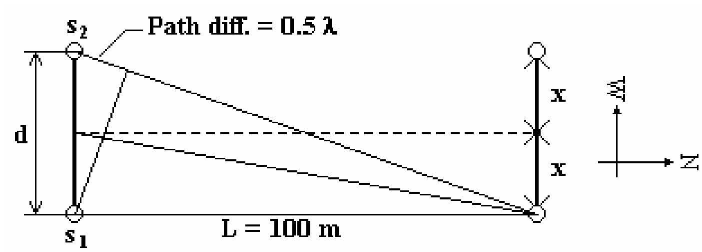
$d = 2.0$ m

$f = 3.0 \times 10^{9}$ Hz

$$\lambda = \frac{c}{f}$$

$$= \frac{3.00 \times 10^{8} \text{ m/s}}{3.0 \times 10^{9} \text{ Hz}}$$

$$= 1.0 \times 10^{-1} \text{ m}$$



$$\frac{x}{L} = \left(n - \frac{1}{2}\right)\frac{\lambda}{d}$$

$$\frac{x}{L} = \frac{\left(\frac{1}{2}\lambda\right)}{d} \text{ for the first nodal lines}$$

$$2x = \left(\frac{\lambda}{d}\right)L$$

$$= \left(\frac{0.10 \text{ m}}{2.0 \text{ m}}\right)(100 \text{ m})$$

$$= 5.0 \text{ m}$$

$$v = \frac{d}{t}$$

$$= \frac{5.0 \text{ m}}{\left(\frac{1}{5}\text{ s}\right)}$$

$$= 25 \text{ m/s}$$

REF: K/U, MC OBJ: 9.5 LOC: WA1.03 KEY: FOP 13.8, p.513
MSC: P

95. ANS:

(a) $\lambda = \frac{v}{f}$

$$= \frac{3.00 \times 10^8 \text{ m/s}}{1.0 \times 10^6 \text{ Hz}}$$

$$= 300 \text{ m}$$

For interference maxima,

$$\sin \theta_n = \frac{n\lambda}{d}$$

$$= n\left(\frac{300 \text{ m}}{400 \text{ m}}\right)$$

$$= \frac{3}{4}n$$

Only possible values for *n* are 0 and 1.

$\theta_0 = 0$

$\theta_1 = 49°$

For maximum intensity the directions would be due north, N49°E and N49°W.

(b) The 180° phase shift turns constructive interference points to destructive, so the three maximum directions become minimum.

REF: K/U, C OBJ: 9.5 LOC: WA1.03 KEY: FOP 13.8, p.512
MSC: P

96. ANS:

$6\Delta x = 6.0 \text{ cm}$

$\Delta x = 1.0 \text{ cm}$

$L = 3.0$ m

$d = 220\ \mu$m

$$\lambda = \Delta x\left(\frac{d}{L}\right)$$

$$= \left(1.0 \times 10^{-2}\text{ m}\right)\left(\frac{220 \times 10^{-6}\text{ m}}{3.0\text{ m}}\right)$$

$$= 7.3 \times 10^{-7}\text{ m}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.4, p.529
MSC: P

97. ANS:

(a) (i) $\sin\theta_1 = \dfrac{\lambda}{w}$

$$= \frac{670\text{ nm}}{12\ \mu\text{m}}$$

$$= \frac{6.7 \times 10^{-7}\text{ m}}{1.2 \times 10^{-5}\text{ m}}$$

$$= 0.0558$$

Thus, $\theta_1 = 3.2°$, and the width is 2(3.2°) = 6.4°.

(ii) $\sin\theta_1 = \dfrac{y_1}{L}$

$$y_1 = L\sin\theta_1$$

$$= 0.30\text{ m}\left(5.58 \times 10^{-2}\right)$$

$$= 1.67 \times 10^{-2}\text{ m}$$

$$= 1.7\text{ cm}$$

The width of the central maximum is $2y_1$, or 2(1.7 cm) = 3.4 cm.

(b) $\lambda = \dfrac{w\Delta y}{L}$

$$\Delta y = \frac{L\lambda}{w}$$

$$= \frac{(0.30\text{ m})\left(6.7 \times 10^{-7}\text{ m}\right)}{1.2 \times 10^{-5}\text{ m}}$$

$$= 1.7\text{ cm}$$

Note that the central maximum is exactly twice the width of the separation of other adjacent nodal lines.

REF: K/U OBJ: 10.2 LOC: WA1.01 KEY: FOP 14.6, p.540
MSC: SP

98. ANS:

$$3\Delta x = 9.0\text{ mm}$$

$$\Delta x = 3.0\text{ mm}$$

$$\lambda = \Delta x\left(\frac{d}{L}\right)$$

$$= (3.0\text{ mm})\left(\frac{0.12\text{ mm}}{80\text{ cm}}\right)$$

$$= \left(3.0 \times 10^{-3}\text{ m}\right)\left(\frac{0.12 \times 10^{-3}\text{ m}}{80 \times 10^{-2}\text{ m}}\right)$$

$$= 4.5 \times 10^{-7}\text{ m (blue)}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.11, p.570
MSC: P

99. ANS:

Since central maximum:

$$2\Delta y = 8.0\text{ cm}$$

$$\Delta y = 4.0\text{ cm}$$

$$\lambda = \frac{w\Delta y}{L}$$

$$w = \frac{\lambda L}{\Delta y}$$

$$= \frac{(640 \text{ nm})(2.0 \text{ m})}{4.0 \text{ cm}}$$

$$= \frac{\left(640 \times 10^{-9} \text{ m}\right)(2.0 \text{ m})}{4.0 \times 10^{-2} \text{ m}}$$

$$= 3.2 \times 10^{-5} \text{ m, or } 32 \ \mu\text{m}$$

REF: K/U OBJ: 10.2 LOC: WA1.01 KEY: FOP 14.11, p.571
MSC: P

100. ANS:

$$t = \frac{\lambda_f}{4}$$

$$\lambda_f = 4t$$

$$= 4(93 \text{ nm})$$

$$= 372 \text{ nm}$$

$$\lambda_a = n_f \lambda_f$$

$$= (1.35)\left(372 \ \mu\text{m}\right)$$

$$= 5.0 \times 10^{-7} \text{ m}$$

This would be green light.

REF: K/U OBJ: 10.4 LOC: WA1.05 KEY: FOP 14.11, p.571
MSC: P

101. ANS:

$$\lambda_f = \frac{\lambda_a}{n_f}$$

$$= \frac{550 \text{ nm}}{1.25}$$

$$= \frac{5.50 \times 10^{-7} \text{ m}}{1.25}$$

$$= 4.4 \times 10^{-7} \text{ m}$$

For destructive interference the film thickness must be $\frac{\lambda_f}{4}$.

$$t = \frac{\lambda_f}{4}$$
$$= \frac{4.4 \times 10^{-7}\ \text{m}}{4}$$
$$= 1.1 \times 10^{-7}\ \text{m}$$

REF: K/U, MC OBJ: 10.5 LOC: WA1.05 KEY: FOP 14.11, p.571
MSC: P

102. ANS:
8 nodal lines = $7\Delta x$

$$\Delta x = \frac{8.0\ \text{cm}}{7}$$
$$= 1.14\ \text{cm, or } 1.14 \times 10^{-2}\ \text{m}$$

$d = 0.15$ mm, or 1.5×10^{-4} m

$$\lambda = \frac{\Delta x d}{L}$$
$$= \frac{\left(1.14 \times 10^{-2}\ \text{m}\right)\left(1.5 \times 10^{-4}\ \text{m}\right)}{3.0\ \text{m}}$$
$$= 5.7 \times 10^{-7}\ \text{m, or } 5.7 \times 10^{2}\ \text{nm}$$

REF: K/U OBJ: 9.5 LOC: WA1.04 KEY: FOP 14.4, p.528
MSC: SP

103. ANS:
$10\Delta x = 13.2$ cm

$\Delta x = 1.32$ m

$$d = \frac{L\lambda}{\Delta x}$$
$$= \frac{(1.5\ \text{m})\left(600 \times 10^{-9}\ \text{m}\right)}{1.32 \times 10^{-2}\ \text{m}}$$
$$= 6.8 \times 10^{-5}\ \text{m, or } 68\ \mu\text{m}$$

$\lambda \propto \Delta x$

$$\frac{\Delta x_b}{\Delta x_r} = \frac{\lambda_b}{\lambda_r}$$

$$\Delta x_b = \frac{\lambda_b}{\lambda_r} \Delta x_r$$

$$= \frac{450 \text{ nm}}{600 \text{ nm}} (1.32 \text{ cm})$$

$$= 0.99 \text{ cm, or } 1.0 \text{ cm}$$

REF: K/U OBJ: 9.5 LOC: WA1.05 KEY: FOP 14.4, p.529
MSC: P

104. ANS:
By particle theory,
$v_g = nv_a$

$$= (1.50)\left(3.00 \times 10^8 \text{ m/s}\right)$$

$$= 4.50 \times 10^8 \text{ m/s}$$

REF: K/U OBJ: 9.4 LOC: WA1.05 KEY: FOP 14.11, p.569
MSC: P

105. ANS:
$7\Delta x = 1.23$ cm

$\Delta x = 0.175$ cm

$$\lambda = \frac{\Delta x(2t)}{L}$$

$$= \frac{(0.75)\left(2(1.9 \times 10^{-3} \text{ cm})\right)}{9.8 \text{ cm}}$$

$$= 6.8 \times 10^{-5} \text{ cm, or } 6.8 \times 10^{-7} \text{ m}$$

REF: K/U OBJ: 10.4 LOC: WA1.01 KEY: FOP 14.7, p.550
MSC: P